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TEMPORARY PAVEMENT MARKING SYSTEMS

FINAL REPORT

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ABSTRACT

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This report documents the laboratory findings only of a study that was undertaken to find additives for conventional traffic marking paint that would make the paint stripe easy to remove by burning and thus make the pavement marking temporary in nature. At the end of the laboratory phase of the project it was the concensus of the Principal Investigator, the NCHRP Project Panel and the NCHRP Program Director that the program should be terminated. The reason for terminating the project midway in its existence was that it was found in the laboratory that the additives necessary to accomplish the desired results carried with their use a degree of hazard to the personnel expected to use them that was greater than could be reasonably accepted.

SUMMARY

The objective of this project was to develop a temporary pavement marking system. The method proposed to accomplish this was to develop an additive package for traffic marking paint. When the occasion presented itself to place temporary markings the paint crew would stop and incorporate the additive package into the paint being used and proceed with the marking operation. The additive package would have little influence on the service performance of the paint and bead system. At such time as desired to remove the markings, a burner would be applied to the painted stripe and the heat from the burner would initiate a reaction of the additive package contained in the dried paint film. The reaction of the additive package would be such that the paint film would be destroyed rapidly, but with little damage to the pavement surface. Ideally the additive package would be composed of materials that are convenient, safe and inexpensive.

After screening many different additives the additive that was found to be ideally suited to greatly accelerate the decomposition by burning of dried films of traffic marking paint was potassium chlorate. The addition of potassium chlorate to conventional traffic marking paint not only causes the traffic marking paint to decompose rapidly on burning but it consolidates the residue and causes it to separate itself from the pavement surface leaving an extremely clean pavement surface. Thus from the chemical laboratory standpoint, potassium chlorate provided the type of solution sought.

Potassium chlorate is the principal ingredient in book or safety matches. Potassium chlorate is a strong oxidizer that carries a considerable degree of risk associated with its use. In prior times its use in the subject application would have probably been readily accepted. Today, product development carries an element of responsibility for the user's safety even if the user fails to observe recommended precautions. In discussing the *pros* and *cons* of the use of potassium chlorate and related materials in this application there are those that have felt the project should proceed using potassium chlorate. The weight of evidence, combined with the opinion of the major manufacturers of potassium chlorate

plus the results of some experiments run in the laboratory, have confirmed the prudence of not proceeding with the use of potassium chlorate.

Soon after the subject project was initiated, the Federal Highway Administration perfected on Contract No. DOT-FH-11-8870 a method to remove pavement markings by high temperature burning with excess oxygen. The Implementation Division of the Federal Highway Administration has since released its Implementation Package* on this method. The significance of this development is that one coat of traffic marking paint can be so easily and rapidly removed by high temperature burning with excess oxygen that conventional traffic marking paint becomes to a degree "temporary" when removed by this method. One coat of traffic marking paint costs approximately $0.015 per foot (0.3 m) in-place. One coat of traffic marking paint can be removed by high temperature burning with excess oxygen at a rate of approximately 5 feet per minute for approximately $0.10 per foot (0.3 m). Thus, any competitive temporary marking system should not cost over approximately $0.0115 per foot (0.3 m) for installation and removal if it is to be cost competitive.

*"Stripe Removal by High Temperature Burning with Excess Oxygen", Implementation Package 77-16, U.S. Department of Transportation, Federal Highway Administration, Offices of Research and Development, Implementation Division, June 1977.

CHAPTER I
INTRODUCTION AND RESEARCH APPROACH

PROBLEM STATEMENT AND RESEARCH OBJECTIVE

Maintenance and construction operations on all classes of highways frequently require temporary pavement markings to provide motorist guidance and safe traffic movement. When existing pavement marking materials, devices, and techniques are used for this purpose, they are difficult to remove in a cost-effective manner without leaving scars on the pavement that may mislead the motorist. There remains a continuing need for a temporary pavement marking system for use on all types of pavement surfaces under all environmental and traffic conditions. Temporary marking systems are defined as those either easily applied and easily removed or those easily applied and self-destructible under controlled conditions.

The specific objectives of the subject project were to:

1. Examine one or more concepts, existing or new, that offer promise for development into workable temporary pavement marking systems. The desired characteristics of these systems include:

    a. Delineation comparable to permanent pavement marking systems, including both yellow and white color, day and night effectiveness, and usability on both asphalt surfacing and Portland cement concrete under all weather conditions.

    b. Easy installation and easy removal or controlled self-destruction such that, under any weather and light conditions, no scars or other visual patterns would appear that might misdirect a motorist.

    c. Absence of any adverse environmental impacts in the process of installing or removing the system.

    d. Ease of implementation.

    e. Cost-effective installation, durability, and removal.

2. Analyze the feasibility of the concept(s) in comparison with existing practice with reference to, but not limited to:

   a. Manpower, equipment, and material costs (application and removal).

   b. Effect on traffic during application and removal.

   c. Traffic control effectiveness.

   d. System durability.

   e. Material and process availability.

   f. Hazards to workmen during application and removal.

   If resources permitted, the analysis was to include field testing of a promising system guided by case and laboratory studies.

SCOPE OF STUDY

The intended scope of the study was to explore the feasibility of one or more candidate solutions by awarding one or more contracts within the limits of available funds. Approximately half of the available funds were awarded to Southwest Research Institute for the subject project to explore the concept of developing an additive package for conventional traffic marking paint that would allow the painted stripe to be easily removed by burning. The subject project was to concentrate on this one approach and not extend itself into other areas such as different paint formulations, prefabricated devices or the like.

RESEARCH APPROACH

The project was divided into the following phases:

1. Laboratory Study
2. Field Testing
3. Specification Preparation
4. Operational Analysis
5. Final Report.

Approximately half of the project effort was assigned to the laboratory study. The approach on this project was to successively investigate the various systems that could serve as an additive package for conventional traffic marking paint that would make the dried paint film destroy itself rapidly on burning with little damage to the pavement. The specific approach followed was to investigate those systems that had little hazard associated with them and proceed stepwise into the more active and more hazardous systems. The systems investigated and the order in which they were investigated are as follows:

1. Hydrated Materials
2. Gas Producing Materials
3. Fuels
4. Oxidizers
5. Fuel-Oxidizer Combinations
6. Other.

It was recognized from the beginning that Southwest Research Institute was responsible for the safety of the system. The approach taken was that no system was justified if it involved risking the safety of any eventual user.

CHAPTER 2
FINDINGS

CONTROL AND TESTING PROCEDURE

All laboratory work was conducted with conventional alkyd base traffic marking paint meeting the Texas Division of Highways specifications. The manufacturer of the specific paint used was the Ennis Paint Company of Ennis, Texas. The various candidate additive materials were initially screened using 4 parts by volume of paint with 1 part by volume of additive. After initial screening those additives showing interesting characteristics were screened at various ratios of paint to additive. The maximum additive ratio employed was 4 parts by paint by volume to 4 parts of additive and the minimum ratio employed was 4 parts of paint by volume to 1/2 part of additive. The additive materials were thoroughly mixed into the paint with a high shear mixer to obtain complete dispersion and then applied at a 16 mil wet film thickness to 6 in. (15 cm) x 6 in. (15 cm) x 2 in. (5 cm) PCC and AC specimen blocks with traffic marking beads dropped on at a rate of 4 lbs (1.8 Kg) of beads per gallon (3.8 ℓ) of paint. The test specimens were allowed to cure in the laboratory for 7 days after which time they were tested. To test the burning characteristics of the different specimens a 2000°F (1100°C) propane in air flame of fixed dimensions was held 1.5 in. (3.7 cm) away from the test specimen at a fixed location for 1 minute and then removed. The burning characteristics were recorded and after the burned area had cooled to ambient temperature the burned area was wire brushed and the residue was blown away with high pressure air to remove the ash and expose the extent of burning and the completeness of removal. A high temperature flame of 4600°F (2500°C) obtained by burning propane with oxygen and the use of excess oxygen was not used for the reason that the combustion takes place so rapidly that comparison of specimens becomes difficult.

Conventional alkyd base traffic marking paint contains approximately 25% resinous solids, 25% pigments, extenders and fillers and 50% solvent. The dried paint film is approximately 50% resinous solids and 50% pigment, extenders and fillers plus glass beads. Dried films of alkyd base traffic marking paint do not burn readily as alkyd resins are not highly flammable. The dried paint films are heavily filled with inert pigments, extenders, fillers and glass beads. This plus the heat sink characteristics of the mass of the pavement serve to retard the rate of burning. By the test procedure described above, control specimens of beaded paint without any additives had an area of complete removal of 1 in. (2.5 cm) in diameter. Those materials with additives were rated against the controls.

HYDRATED MATERIALS AS ADDITIVES

In concept, the addition of a hydrated material to paint would at some temperature cause liberation of the water of hydration as a vapor and/or steam which would aid in the destruction of the dried paint film. The following hydrated materials were screened as additives.

	Molecules of Hydrated Water
Alum	24
Alumina Hydrate	3
Borax	10
Calcium Sulfate	2
Sodium Sulfate	10
Calcium Chloride	6
Sodium Carbonate	1

Two forms of alumina hydrate were obtained, one from Reynolds and the other from Kaiser. In testing the resulting films by burning, no improvement was observed over the controls due to the presence of the additives. Some of the additives are known fire retardants, and it was thought that they might retard the rate of burning. In this application their influence on retarding the rate of burning could not be perceived.

GAS PRODUCING MATERIALS AS ADDITIVES

The following gas producing materials were screened as additives:

Sodium Bicarbonate

Azodicarbonamide - Type 1

Azodicarbonamide - Type 2
Ammonium Phosphate-Dibasic
Ammonium Phosphate-Monobasic
Baking Soda
p-Toluene Sulfonyl Hydrazide
4,4' Oxybis (benzene sulfon hydrazide)
5-Phenyl Tetrazole
Proprietary Hydrazine Derivative (Uniroyal).

In testing the resulting films by burning no improvement was observed over the controls due to the presence of the additives. Attention was then directed to intumescent paint films which expand on heating and were considered to be a possible route to a solution of the problem. The principal additives in an intumescent coating are pentaerythritol, melamine, a blowing agent and diammonium phosphate. These additives were studied individually and combined as additives for traffic marking paint. It was found that on burning the effective agent in expanding the dried paint film is diammonium phosphate. Unfortunately, diammonium phosphate is also a fire retarding agent. Because of this the underlying paint is protected and complete destruction of the paint film is not achieved.

FUELS AS ADDITIVES

The following fuel materials were screened as additives:

Magnesium Powder
Aluminum Powder
Zinc Powder
Phosphorous Pentasulfide
Red Phosphorous
Sulfur
Micronized Polyethylene
Polystyrene Beads - 200 mesh.

It was anticipated that the metal powders and red phosphorous in particular would greatly accelerate the decomposition of the paint films on burning due to the fact that these additives are common in pyrotechnic formulations. While the subject additives added color and brillance to the flames on burning they did not offer any significant improvement in paint film destruction.

OXIDIZERS AS ADDITIVES

The following oxidizer materials were screened as additives:

Potassium Nitrate
Barium Nitrate
Sodium Perborate
Sodium Chlorate
Potassium Persulfate
Benzoyl Peroxide.

It was found on testing that the materials containing barium nitrate and sodium chlorate flared up and burned much more rapidly than any of the other materials or the controls. It was also observed that both of these materials reacted with constituents of the paint to yield vitrous glass-like reaction products that were both physically tough as well as adherent to the pavement surface, which was undesirable. In view of this, attention was directed to the use of other oxidizer materials.

In the course of this work potassium chlorate which had not been examined in the earlier screening was tested and was found to provide a near perfect solution, in that dried traffic paint films containing potassium chlorate burned off at a very accelerated rate and the ash literally separated itself from the pavement surface, which with the lightest brushing exposed a clean and undamaged pavement. Experiments with the use of 0 to 70 parts of potassium chlorate to 100 parts of paint by volume were made and it was found that 50 parts of potassium chlorate to 100 parts of paint by volume was more than adequate.

Test stripes were placed using 50 parts by volume of potassium chlorate with 100 parts by volume of paint. The stripes were beaded and burned off with a regular low temperature propane in air burner and with a high temperature, propane-oxygen, excess oxygen burner. The presence of potassium chlorate results in an increase in the rate of removal using either burner types. Low temperature burning of unaltered traffic marking paint stripes proceeds at a rate of about 1 foot (.3 m) per minute. High temperature burning with excess oxygen of unaltered traffic marking paint stripes proceeds at a rate of about 5 feet (1.7 m) per minute. Low temperature burning of stripes containing potassium chlorate proceeds at a rate of about 5 feet (1.7 m) per minute. High temperature burning with excess oxygen of stripes containing potassium chlorate in amounts mentioned above proceeds at a rate of about 10 feet (3.3 m) per minute. Thus, the degree of improvement in the rate of removal by the use of potassium chlorate was considered sufficient to justify its use, in that one would not want to go to the trouble and expense of handling an additive if it did not offer a substantial increase in the rate of removal.

Several associated studies were made related to the use of potassium chlorate. Quart samples of traffic marking paint and traffic marking paint with potassium chlorate were purposely overheated in open containers and ignited and no explosion occurred. The samples with potassium chlorate burned violently. Burning operations were purposely initiated and then discontinued to determine if the presence of potassium chlorate would allow combustion of the stripe to proceed without the presence of the burner to sustain the combustion. In every instance, when the burner was removed the stripe was self-extinguishing. In another experiment a stripe containing potassium chlorate was repeatedly struck hard blows with sharp and blunt objects such as chisels and ballpeen hammers to determine if such blows would initiate combustion. In no instance did the strikes initiate combustion. Match grade (200 mesh) potassium chlorate is in the $0.30 per pound price range and could be an easily affordable additive. At that point it appeared that potassium chlorate was the perfect additive for the subject application.

FUEL-OXIDIZER COMBINATIONS AS ADDITIVES

Additive packages of the following materials in varying ratios were made and screened.

Zinc powder
Sulphur powder

Aluminum powder
Sulphur powder

Magnesium powder
Sulphur powder

Magnesium powder
Barium nitrate

Magnesium powder
Barium nitrate
Sulphur powder

Aluminum powder
Barium nitrate
Sulphur powder

Iron oxide
Aluminum powder

Iron oxide
Barium nitrate

Magnesium powder
Sodium nitrate.

The dried paint films containing these materials were tested and it was found that the additive packages accelerated the decompositon of the paint films, but they offered no advantages over the use of oxidizers alone and in particular over the use of potassium chlorate. These combinations were considered more hazardous than the use of oxidizers alone and they presented dispersion and pigmentation problems. For these reasons work on this group of additives was not pursued.

OTHER MATERIALS AS ADDITIVES

At this point, attention was directed to a category of materials that might best be described as other materials not previously tested. These included:

Hydroxypropyl Methylcellulose

Starch

Chlorinated Rubber

Borax Glass

Gum Arabic

Boric Acid

Aluminum Stearate

Dicyclopentadiene

Cyclodiene Dimer Concentrate

Urea

Chlorinated Paraffin

Styrene-butadiene Latex

Sugar

Lacquer - Clear and Pigmented

Pectine.

None of these materials proved interesting with the exception of those formulations containing sugar. Further experiments were run using powdered sugar (confectioners sugar). On heating, the presence of sugar in the dried paint film causes the creation of bubbles in the paint film which work to destroy the paint film. However as heating progresses the sugar turns to caramel and ultimately to a dark char that remains on the pavement and is insoluable. This is unacceptable.

CHAPTER III

INTERPRETATION, APPRAISAL, APPLICATION

HAZARDS OF POTASSIUM CHLORATE

Based on the laboratory work the only additive material found that performed in the desired manner was potassium chlorate. Its performance was in all respects outstanding.

Potassium chlorate is the principal ingredient in book or safety matches which people commonly carry on their person. Safety matches ignite on contact with the phosphorous containing striking surface on the match cover. Before proceeding into field testing of this system, the Pennwalt Corporation was contacted. Pennwalt is the largest manufacturer of potassium chlorate in the United States and after the proposed system was described to them in detail, they expressed considerable reservations about the system. They were particularly concerned over the handling of potassium chlorate by uninstructed or poorly instructed personnel. For example, a paint crew member engaged in adding powdered potassium chlorate powder deposited on this shirt sleeve or other clothing. Later in the day if that clothing were to encounter an ignition source such as a cigarette or a welding spark, then the sleeve or other clothing might ignite and burn violently with great harm to the individual. Some laboratory rags were suitably dusted with potassium chlorate powder and subsequently ignited and it was found that indeed they burned violently. Thus, the system that was found to perform in exactly the manner envisioned and set forth in the proposal unfortunately cannot be recommended because of the hazard involved in its use.

HIGH TEMPERATURE BURNING WITH EXCESS OXYGEN

The FHWA had underway when the subject project was initiated a contract (DOT-FH-11-8870) with the Institute on "Method to Remove Pavement Markings". One coat of traffic marking paint can be so easily and rapidly removed by high temperature burning with excess oxygen that conventional traffic marking paint becomes "temporary" when removed by this method. The equipment developed for that project consists of a burner tip 6 in. (15 cm) long by 0.5 in. (1.2 cm) wide that provides a series of small flames fueled by a mixture of propane and oxygen. Behind this tip is a second tip of identical configuration that directs pure oxygen at the surface being burned. The tips are positioned approximately 1.5 in. (3.8 cm) above the surface and are mounted on a small hand propelled cart with the supply hoses running back to a following truck on which the propane and oxygen bottles are mounted. The combination of the 4,800°F (2,700°C) flame plus the excess oxygen serves to rapidly destroy the unwanted paint film. The effect is that of flash burning with very little heating of the substrate. The mass of the pavement absorbs the heat at such a rate that it is possible to touch the surface that has been burned as close as 2 ft. (0.6 m) behind the burner when it is in operation. A wire brush is used behind the burner to sweep away the paint film residue. Most highway department maintenance yards have propane and oxygen bottles, regulators and hoses and can be equipped to perform the removal of unwanted pavement markings by this method for several hundred dollars. The rate of removal is approximately 5 ft. (1.5 m) per minute.

SYSTEMS ECONOMICS

The Texas Division of Highways has been experimenting with high temperature burning with excess oxygen and have burned off many thousands of feet of stripe on both AC and PCC pavements using this method. Their very preliminary and unofficial estimates suggest that stripes may be removed by high temperature burning with excess oxygen for approximately $0.10 per foot (0.3 m). Their comparable cost for sandblasting is $0.32 per foot (0.3 m). The cost of applying one coat of traffic marking paint is generally thought of as costing approximately $0.014 per foot (0.3 m). Thus, the cost of applying one coat of traffic marking paint and removing it by high temperature burning with excess oxygen is approximately $0.115 per foot (0.3). This system is thought to represent a very low-cost temporary marking system. Based on cost estimates made by Southwest Research Institute stripe removal by high temperature burning with excess oxygen is less expensive than grinding, low temperature burning, sandblasting, water blasting, chemical and steam removal methods.

CHAPTER IV
CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

It was concluded in the subject project that:

1. It is possible to make an additive package for traffic marking paint from potassium chlorate that will allow one to very rapidly, efficiently and economically place and remove pavement markings and thus have a temporary marking system. Unfortunately, potassium chlorate has certain hazards associated with its use that precludes recommendation for use in temporary markings.

SUGGESTED RESEARCH

It is suggested that if any of the methods proposed by others in the original proposals indicate potential above and compete with the use of paint and removal by high temperature burning with excess oxygen, they be pursued.